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ANNUAL PROGRESS REPORT

Estimation of Juvenile Striped Bass Relative Abundance in the Virginia portion of Chesapeake Bay

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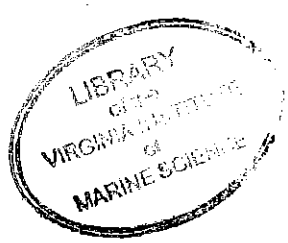

ACKNOWLEDGEMENTS

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PREFACE

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile striped bass seine survey from 1967 through 1973 and from 1980 through the present. The primary objective has been the monitoring of the relative annual recruitment success of juvenile striped bass in the spawning and nursery areas of Lower Chesapeake Bay. Initially (1967-1973), the survey was funded by the U.S. Fish and Wildlife Service and when reinstated in 1980 with funding from the National Marine Fisheries Service under the Emergency Striped Bass Study program. Commencing with the 1988 annual survey, support of the program has been jointly made through the Sportfish Restoration Program (Wallop-Breaux Act), administered through the U.S. Fish and Wildlife Service and the Virginia Marine Resources Commission. This report summarizes the results of the 2001 sampling period and compares these results with the previous work.

Specific objectives planned for the 2001 program were to:

1. Measure the relative abundance of the 2001 year class of striped bass from the James, York and Rappahannock river systems.
2. Quantify environmental conditions at the time of collection.
3. Examine relationships between juvenile striped bass abundance and measured or proxy environmental and biological data.

INTRODUCTION

The estimation of juvenile striped bass abundance in Virginia waters, funded by the U.S. Fish and Wildlife Service, is part of a coast-wide sampling program of striped bass recruitment conducted from New England to North Carolina under the coordination of the Atlantic States Marine Fisheries Commission (ASMFC). Virginia's efforts started in 1967 with funding from the Commercial Fisheries Development Act of 1965 (PL88-309) and continued until 1973 when the program was terminated. It was re-instituted in 1980 with Emergency Striped Bass Study funds (PL 96-118, 16 U.S.C. 767g, the "Chafee Amendment"), and since 1989 has been funded by the Wallop-Breaux expansion of the Sportfish Restoration and Enhancement Act of 1988 (PL 100-448 known as the Dingle-Johnson Act).

The Atlantic Coast Striped Bass Interstate Fisheries Management Plan was developed by ASMFC in 1981, then adopted by the Virginia Marine Resources Commission (VMRC) in March 1982 (Regulation 450-01-0034). Amendment IV to the plan requires "producing states" (e.g. Virginia, Maryland, Delaware and New York) to develop and support monitoring programs of recruitment levels. This became a mandate when Congress passed the Atlantic Striped Bass Conservation Act in 1984 (reauthorization 1991, PL102-130). To remain in compliance with the Act, each state must adhere to all provisions in the interstate FMP (ESBS 1993). Virginia has done this through December 2001.

Originally, the Virginia program used a 6' x 100' (2m x 30.5m) x 0.25" (6.4mm) mesh bag seine,

but after comparison tows with Maryland gear, 4' x 100' x 0.25" mesh (1.2m x 30.5m x 6.4mm) showed virtually no statistical differences in catch, Virginia adopted the "Maryland seine" (Colvocoresses 1984). The original purpose of the gear comparison study was to standardize methods thereby allowing a Bay-wide examination of recruitment success (Colvocoresses and Austin 1987). This was never realized however, for various differences in data handling (MD: arithmetic index, VA: geometric index) and state politics. A Bay-wide index using a weighted (by river spawning area) geometric mean was finally developed in 1993 (Austin, Colvocoresses and Mosca 1993).

METHODS

Field sampling was conducted during five approximately biweekly sampling periods from July through mid-September of 2001. During each sampling period the seine was hauled at eighteen historically sampled sites (index stations) and twenty-two auxiliary stations along the shores of the James, York and Rappahannock systems (Fig. 1). Addition of the auxiliary sites in 1989 was made to provide better geographic coverage and create larger within-river-system sample sizes so that trends in juvenile abundance can be meaningfully monitored on a system-by-system basis, particularly as the stock size increases and the nursery ground expands.

One seine haul was made at each auxiliary station, and two duplicate hauls made at each index station during each sampling round. Collections were made by deploying a 100' (30.5m) long, 4' (1.22m) deep, 1/4" (0.64cm) mesh minnow seine perpendicular to the shoreline (either until the net was fully extended or a depth of approximately four feet was encountered), pulling the offshore end

down-current and back to the shore. In the case of index stations, all fish taken during the first tow were removed from the net, measured, and held in water-filled buckets until after the second tow. All fish collected were identified and counted, and all striped bass and all individuals or a sub-sample of at least 25 individuals of other species measured to the nearest mm fork length (or total length if appropriate). Salinity, water temperature, pH and dissolved oxygen concentrations were measured after the first haul using a Hydrolab Reporter® water quality sampler. Sampling time, tidal stage and weather conditions were recorded at the time of each haul. When two hauls were made, an intervening period of 30 minutes was allowed between hauls and the first sample was processed during this interlude. All fishes captured, excepting those preserved for life history studies, were returned to the water at the conclusion of sampling.

In the present report, comparisons with prior years will be made on the basis of the 'primary nursery' standardized data set (Colvocoresses 1984), i.e. only the data collected from the months and area covered during all surveys will be included in the analyses. Data from the auxiliary stations will not be included since there is no direct basis for comparison. Since the frequency distribution of catch size of these collections is extremely skewed and approximates a negative binomial distribution (Colvocoresses 1984), a logarithmic transformation ($\ln(x+1)$) was applied in order to normalize the data prior to analyses (Sokal and Rohlf 1981). Subsequently computed mean values were retransformed (i.e. the geometric mean) and scaled up arithmetically to allow comparison with Maryland data.

Mean catch rates are contrasted by comparing 95% confidence intervals. Reference to "significant" differences between means in this context will be restricted to cases of non-overlap by

these confidence intervals. Because the standard errors are calculated using the transformed (logarithmic) values, confidence intervals on the retransformed and adjusted scale are non-symmetrical.

RESULTS

Objective 1: Measure the relative abundance of the 2001 year class of juvenile striped bass from the James, York and Rappahannock river systems.

A total of 2624 young-of-the-year striped bass were collected from 180 seine hauls during the 2001 index station sampling and an additional 846 age 0 striped bass were collected in 105 hauls at the auxiliary sites (Table 1, Fig. 1). The adjusted overall mean catch per seine haul (CPUE) for the index stations was 14.17, the fifth highest index in Virginia (Table 2, Fig. 2). This value was more than twice the overall average index of 6.79 (significantly different) and was near although slightly less than the 2000 value (16.18). The index for each river system was higher than its overall average and each individual river was more than its respective overall average.

The 2001 catch in the James drainage was 24.03, three times the overall average of 8.50 (Table 3, Fig. 3) and surpassed only by the 2000 and the record 1996 indices. Juvenile striped bass were widely distributed throughout the James system in 2001 and consistent catches were made at nearly all of the sampling sites. (Table 1, Fig. 4). Several sites (J12, J56, and J78) produced only small catches but fish were captured on most visits. Only three of seventy site visits failed to produce striped bass for the entire James system.

The main-stem James catch rate (22.19) was three times higher than its overall average of 7.51. The Chickahominy catch rate (28.12) decreased slightly in 2001 but was two and one-half times higher than its overall average of 10.85 (Table 1; Fig. 4). J46 was the highest producing index site in the James River while J22 was the best producing auxiliary site. While slightly lower than 2000, the index in the Chickahominy remained well above the historical average. Catches during round 1 in the Chickahominy were very high and dropped significantly in the remaining four rounds.

The 2001 index in the York drainage (8.52) was twenty-five percent lower than the 2000 value and while higher than the historical average (5.45), was not significantly higher (Table 3, Fig. 3). The index in the Pamunkey (12.80) and the Mattaponi (6.12) were also above their respective overall averages (Pamunkey = 6.50, Mattaponi = 4.75). The Pamunkey index decreased by almost fifty percent from 2000 but was nearly double its historical average while the Mattaponi was only slightly lower than 2000 but higher than its historical average.

All sites in the mainstem York River are auxiliary sites. Striped bass were caught at all three sites but only Y28 produced striped bass during all rounds in 2001 (Table 1; Fig. 5). Striped bass were captured at Y15 during rounds 1, 2, and 5 while Y21 produced fish in round 4. Catches on the Mattaponi River were highest at M41, an index site near the center of the index area and at M37, an adjacent auxiliary site. Sites in the center and lower section of the index area produced the best catches of striped bass.

In the Pamunkey River, highest catches occurred at P50, the upper index site (Figure 6). While catches were made during each sampling visit to P42, they were generally small. P36, the downriver

auxiliary site was more productive than P42 and the upriver auxiliary site (P55) produced consistent catches of striped bass. P45 had good catches of striped bass during rounds 1 and 2 but catches fell dramatically in later rounds.

The 2001 index in the Rappahannock River was 14.60, more than double the value of the historic average of 6.88 (Table 3). Highest catches were at the three uppermost index sites (R44, R50, R55) and R60, the adjacent upriver auxiliary site (Table 1, Fig. 7). Up-river auxiliary sites (R65 through R76) produced fish during most sampling visits though not in great numbers. The two lower index sites, R28 and R37, produced low numbers of stripers on most visits except round 1 when high catches were recorded at each site. R12, a downriver auxiliary site became inaccessible to sampling and was not sampled during round 1. The station was moved downriver and resituated at R10. This site produced striped bass in rounds 2 and 3 while R21 produced fish in rounds 2, 3, and 5.

Because the number and precise timing of sampling rounds has varied throughout the history of the sampling program, results by sampling period cannot be directly compared. However, temporal usage of the nursery area can be evaluated by comparing round by round results with historical monthly averages. Generally, catch rates are highest during July and early-August and taper off in the later rounds of August and September and in 2001 this overall pattern was observed (Table 4). However, the disparity in catches between the first and subsequent rounds was particularly evident in 2001. In the James/Chickahominy system, there were several site visits in rounds 1 and 2 that produced over 100 fish per tow and later visits produced less than 10 fish per tow. Similar disparities were evident on the other systems.

Overall, catches for all sites fell 51 percent (1530 to 744) from round 1 to round 2 (Table 1). Both the James system and the Rappahannock exceed this figure. The James drop (62%) was due to the precipitous drop in the Chickahominy River catches (94%). The York system did not have as great a drop between rounds 1 and 2 but the drop was greater than 50 percent between rounds 2 and 3. At the index sites the disparity between rounds 1 and 2 was 68 percent (1315 vs 421) while the historical decline at the index sites is 19 percent (Table 4).

The York (91% decrease) and the Rappahannock (90%) catches were similar to 2000 in that they dropped nearly 90 percent between rounds 1 and 5. The James however fell 75 percent in 2001 while 2000 levels fell only 29 percent (Austin et al, 2001). Historically, the average decline between rounds 1 and 5 (for all rivers) has been 64 percent at the index sites.

A total of 286 young-of-the-year (y-o-y) were captured at the former Bluefish Seine Survey sites in the lower James River, Chesapeake Bay and seaside Eastern Shore. Most fish (186) were captured at Willoughby Spit at the mouth of the James River and of those 184 were captured on May 29. Eighty-four striped bass were captured at Bloxom; 45 in June, 30 in July, 7 in August, and 2 in September. Bloxom is located on the Bay side of the Eastern Shore in Pocomoke Sound. Fish captured at this site probably came from nearby nursery areas. Fourteen fish were captured at four different sites in the lower Bay and two fish were captured at Wachapreague which is on the ocean side of the Eastern Shore.

Objective 2: Quantify environmental conditions at the time of collection.

Collection information and pertinent environmental variables recorded at the time of each collection in 2001 are given in Tables 5 through 8. Generally, direct round by round comparisons of environmental and water quality parameters are difficult because of local site conditions and variations, so they must be examined on a broader basis.

Generally, salinities were only slightly higher in 2001 than in 2000 (Table 5)(Austin et al, 2001). Salinities at down-river index sites were higher than those recorded in 2000. The Palmer Drought Index (Palmer, 1964) and data from the National Climate Data Center indicated that the spring of 2001 was near a normal moisture condition and the data for Virginia indicated normal or slightly wet conditions in March and May while February and April had below normal precipitation (April was "much below normal"). NCDC data showed normal rainfall amounts through late summer when a moderate drought began that lasted through late fall.

Overall, water temperatures were near normal in 2001 (Table 6). The normal pattern of higher temperature in the early rounds and temperature slowly declining during the later rounds was observed in 2001. Water temperatures by round may have varied slightly from 2000 readings but there were no major weather anomalies that affected water temperatures during the 2001 sampling season. Water temperature readings in these estuaries are not only affected by the long term weather patterns of summer but significant variations from day to day and river to river can be caused by time of sampling (morning versus afternoon, etc) and local events such as thunderstorms. We sample the shallow shoreline areas that are easily affected by such conditions and these effects on site specific striped bass abundances are not easily assessed.

Dissolved oxygen levels were generally within the norms expected during this sampling period (Table 7). No depressed readings that might affect catches were observed in 2001.

The pH levels during the 2001 sampling were near normal for most areas during 2001 (Table 8). Generally the James and Rappahannock systems have pH values that are slightly basic. The Pamunkey River is near neutral pH and the Mattaponi River has pH values that are slightly acidic. In 2001, pH values in the Mattaponi were near neutral.

All index sites were completed without interruption although some hydrological data were not collected due to malfunctions of the water quality instrument.

Objective 3: Examine relationships between juvenile striped bass abundance and measured or proxy environmental and biological data.

Overall distribution of catch rates with respect to salinity in 2001 followed the normally observed pattern of higher catches at lower salinities within the primary nursery area (Table 9). Figure 8 shows the relationship of juvenile striped bass catches with respect to historical salinity gradients within each river system. This figure shows the data from 1967 to 1999 and represents the long term trend while Figure 9 shows the salinity gradients for 2001. Overall, catches were highest in the areas of lowest salinities (0-4.9ppt) for both the long term and 2001.

Catch rates with respect to water temperature in 2001 clearly adhered to the pattern seen in most years, i.e. catch rates varied directly with water temperature at the time of collection (Table 10).

Most fish are captured in the 25-30°C range which is the normal water temperature range during our sampling. As noted in previous reports, this relationship is considered to be largely the result of a coincident downward progression of both catch rates and temperature as the survey season progresses (at least after the second sampling round) rather than any causative effect of water temperature on juvenile distribution. The growth and subsequent gear escapement or movement of fish into deeper waters usually play a larger role in this trend. Generally, catches within the sampling season are not governed by water temperatures and the overall relationship between catch and water temperature within the sampling season is probably coincidental.

Data on pH, dissolved oxygen concentrations and secchi disc visibility depth readings have been recorded with the seine collections since the expansion of the sampling program in 1989. Dissolved oxygen concentrations generally exceeded 5mg/l outside of the York system, and have little or no effect on juvenile striped bass distributions. pH values during our sampling are generally near neutral to slightly basic outside of the Mattaponi River and like dissolved oxygen appear to have little effect. However the Mattaponi River reading were slightly basic in 2001 compared to previous years but no distribution effects were discerned. Secchi disc readings are a relative measure of turbidity and can affect catches in two ways: when turbidity is extremely high fish are more vulnerable to our gear and when it is low (e.g. greater clarity) net avoidance becomes a potential problem. We saw no high turbidity episodes in 2001 and though secchi readings are not presented herein, the data are collected, stored, and are available upon request.

Data and indices for other species captured during the juvenile striped bass abundance survey can be accessed on the web at http://www.fisheries.vims.edu/seinedata/.

DISCUSSION AND CONCLUSIONS

The striped bass juvenile index recorded in the Virginia Chesapeake Bay nursery areas in 2001 was significantly higher than the historical average (Table 2) and slightly lower than the 2000 index (Austin et al, 2001). It was the fifth highest index recorded since 1985 after stringent harvest regulations of the ASMFC Interstate Fisheries Management Plan were implemented in 1982. All rivers and river systems were above historical averages and all except the Mattaponi and York system were significantly higher. The James system exerted the greatest positive influence on the overall index while the York system exerted the least.

The spring of 2001, with the exception of April, in the coastal plain of Virginia had near normal to slightly elevated rainfall patterns. Salinities remained near normal but monthly rainfall varied considerably from early spring until mid-summer when a moderate drought began. Distribution of juvenile striped bass was generally within the confines of the index area, however the catch of 184 stripers at the mouth of the James river on May 29 suggests an early downriver dispersal of some striped bass before sampling in the defined index area began. These fish were probably unavailable to index sampling in July. The average fork length of those downriver fish in May was 29 mm (N=50) while those captured at J29 on July 9th averaged 56mm (N=47). Based on findings by Kline, 1990, the birthdate of these two measured samples of striped bass were very close to one another, i.e. early to mid-April. Even though April had above average temperatures and "much below normal" rainfall, good spawning and survival occurred.

Juvenile striped bass captured at Bloxom throughout the summer probably moved into Pocomoke

Sound from a nearby Eastern Shore nursery area. Spatial dispersal of earlier spawned recruits responding to high recruitment levels in the nursery area probably expanded the normal nursery to include the Virginia portion of Pocomoke Sound. The Maryland striped bass index was high in 2001 (E. Durrell, personal communication) (Baywide=50.8; Nanticoke=40.1; Choptank==201.9) and these fish probably dispersed outward into nearby areas in the Bay.

The strong recruitment of juvenile striped bass in 2001 was likely a result of the normal to slightly elevated rainfall conditions that produced sufficient river flow during March and May, cool March temperatures, and an increasing spawning stock. Conditions resulting from these flow/temperature conditions were more conducive to successful recruitment in the Virginia portion of Chesapeake Bay. Wood, (2000) found that weather conditions in March affect springtime temperatures and rainfall (thus river flow) and can affect the recruitment success of anadromous fishes. With the persistence of the winter Ohio Valley High climate pattern, cold and fresh conditions extend into March and as a result the suitable anadromous fish nursery areas are extended both spatially and temporally benefitting recruitment. When March is dominated by the Azores-Bermuda High, warm and dry conditions are present in spring which is not as conducive to anadromous fish recruitment success. Though April rainfall was below normal and temperature was above normal, these conditions did not appear to adversely affect recruitment in 2001.

Striped bass recruitment success in the Virginia portion of Chesapeake Bay remains variable between years and between the different nursery areas within years. These fluctuations had been bracketing a much higher average until 1999 when weak recruitment occurred. However, with

favorable survival and recruitment conditions, a strong recruitment of striped bass was seen in 2001 continuing the success seen in 2000. The strong yearclasses in 1998, 2000, and 2001 should adequately overcome any yearclass failure that may have resulted from the low 1999 recruitment. Continued monitoring of recruitment success will be an important factor in determining management strategies to protect the spawning stock of Chesapeake Bay striped bass.

The addition of auxiliary stations in 1989 has provided better areal coverage of the nursery areas. These additional areas of coverage have revealed that in years of high or low river flow there may be a shift in the traditional nursery areas up or down-river plus in years of high abundance the nursery area generally expands both up and down river. Figures 4-7 represent average catch per haul at all sites and past analyses have demonstrated that catches are consistently higher in the first haul of any given set of seine hauls. Since only one haul is made at the auxiliary sites, the figures may over-emphasize the relative contribution of the auxiliary sites. They are included only to demonstrate the spatial distribution of the yearclass. They are important in that they allow us to see a shift in distribution that could be affecting catches at the index sites. Reducing hauls at index sites to one per site and including some of the auxiliary sites in the index and deleting others may lead to a more precise estimate of relative year-class strength but it will undoubtedly elevate the recalculated indices (Rago et al, 1996).

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Table 1. Catch of young-of-the-year striped bass per seine haul during the 2001 survey. Two hauls were made per sampling round at each of the historical index stations (bold).

Drainage																
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78	TOT.
	Round															
	1	3	14	22/26	44/25	15	137/88	233/11	52/31	28	6/2	16	3	15	10	781
	2	3	121	4/5	6/4	1	19/2	6/3	32/30	9	0/1	31	6	7	6	296
	3	1	10	13/2	15/8	11	22/13	6/5	7/17	9	1/2	8	0	8	2	160
	4	1	31	13/21	25/23	11	16/22	5/10	16/51	10	0/3	2	16	2	0	278
	5	0	8	23/12	21/13	9	7/12	2/4	44/10	2	5/2	8	5	11	1	199
																1714
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55						
	1	11	0	5	5	2/1		25/12	76/39	7						183
	2	7	ns	3	9	2/0		20/46	16/13	15						131
	3	0	0	5	15	5/1		3/1	23/7	7						67
	4	0	5	9	1	1/3		8/3	36/15	7						88
	5	1	ns	5	4	1/0		1/2	4/4	5						27
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52						
	1				32/6	18	33/18	11/11	2/0	0						131
	2				4/3	61	20/14	4/1	2/2	1						112
	3				5/7	11	11/6	2/0	8/0	1						51
	4				3/0	5	14/11	1/1	0/0	ns						35
	5				0/1	0	0/1	0/0	0/0	0						2
																827
RAPPAHANNOCK	Station	R10	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	1	ns	0	20/10	63/58		1	37/44	49/12	65/12	39	7	11	7		435
	2	1	3	5/3	0/0		1	17/10	46/18	46/17	30	4	1	3		205
	3	1	3	7/2	2/0		0	12/7	17/10	69/28	6	9	0	9		182
	4	0	0	0/1	1/0		0	3/0	9/3	9/14	9	3	0	10		62
	5	0	3	4/1	0/0		0	0/1	1/5	12/10	4	3	1	ns		45
																929
																3470

Table 2. Catch of young-of-the-year striped bass per seine haul in the primary nursery area summarized by year (adjusted mean = retransformed mean of ln (x+1) * 2.28, the ratio of overall arithmetic and geometric means through 1984).

Year	Total	Mean ln (x+1)	Std. Dev.	Adjust Mean	C.I. (± 2 SE)	N
1967	209	1.07	0.977	4.40	2.82-6.45	53
1968	208	0.93	0.900	3.50	2.35-4.94	66
1969	207	0.78	0.890	2.71	1.80-3.84	77
1970	461	1.31	1.121	6.17	4.27-8.63	78
1971	178	0.76	0.857	2.61	1.76-3.64	81
1972	96	0.39	0.575	1.07	0.73-1.45	119
1973	139	0.53	0.790	1.59	0.98-2.32	87
1980	228	0.74	0.900	2.52	1.68-3.53	89
1981	165	0.52	0.691	1.57	1.10-2.09	116
1982	323	0.78	0.967	2.71	1.85-3.74	106
1983	296	0.91	0.833	3.40	2.53-4.42	102
1984	597	1.09	1.059	4.47	3.22-6.02	106
1985	322	0.72	0.859	2.41	1.78-3.14	142
1986	669	1.12	1.036	4.74	3.62-6.06	144
1987	2191	2.07	1.228	15.74	12.4-19.8	144
1988	1348	1.47	1.127	7.64	6.10-9.45	180
1989	1978	1.78	1.119	11.23	9.15-13.7	180
1990	1249	1.44	1.096	7.34	5.89-9.05	180
1991	667	0.97	0.951	3.76	2.96-4.68	180
1992	1769	1.44	1.247	7.32	5.69-9.28	180
1993	2323	2.19	0.975	18.12	15.4-21.3	180
1994	1510	1.72	1.034	10.48	8.66-12.6	180
1995	926	1.22	1.045	5.45	4.33-6.75	180
1996	3759	2.41	1.227	23.00	18.8-28.1	180
1997	1484	1.63	1.097	9.35	7.59-11.4	180
1998	2084	1.92	1.139	13.25	10.8-16.1	180
1999	442	0.80	0.862	2.80	2.19-3.50	180
2000	2741	2.09	1.240	16.18	13.06-19.92	180
2001	2624	1.98	1.271	14.17	11.33-17.60	180
Overall	31195	1.38	1.183	6.79	6.46-7.13	4029

Table 3. Catch of young-of-the-year striped bass per seine haul in primary nursery area in 2001 summarized by drainage and river.

Drainage River	2001 Total Fish	2001 Adjust. Mean	2001 C.I. (2 ± SE)	2001 N (sites)	All Years combined Total Fish	All Years combined Adjust. Mean	All Years combined C.I. (± 2 SE)	All Years combined N (sites)
James	1260	24.03	17.43-32.82	60	12292	8.50	7.81-9.24	1338
James	637	22.19	15.10-32.17	40	7051	7.51	6.78-8.31	900
Chickahom.	623	28.12	15.49-49.72	20	5241	10.85	9.36-12.52	438
York	604	8.52	5.84-12.08	70	9054	5.45	5.03-5.88	1522
Pamunkey	370	12.80	7.43-21.16	30	4707	6.50	5.74-7.33	646
Mattaponi	234	6.12	3.59-9.75	40	4347	4.75	4.29-5.25	876
Rappahannock	760	14.60	9.18-22.57	50	9849	6.88	6.23-7.58	1169
Overall	2624	14.17	11.33-17.60	180	31195	6.79	6.46-7.13	4029

Table 4. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2001 summarized by sampling period and month.

	2001				All Years Combined			
Month	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)
July (1st)	1315	45.22	29.40-68.94	36	9400	9.95	8.95-11.03	854
(2nd)	421	13.98	8.80-21.59	36	7635	7.65	6.86-8.50	865
Aug. (3rd)	344	12.89	8.60-18.86	36	5493	6.08	5.46-6.74	857
(4th)	341	10.47	6.22-16.86	36	5117	6.23	5.52-7.00	721
Sept. (5th)	203	5.78	3.29-9.38	36	3345	5.50	4.84-6.23	595

Table 5. Salinity (parts per thousand) recorded at 2001 seine survey stations. York system includes Pamunkey and Mattaponi Rivers.

Drainage															
JAMES	Station	J12	J22	J29	J36	J42	C1	C3	J46	J51	J56	J62	J68	J74	J78
	Round														
	1	4.40	7.30	3.80	0.80	0.40	0.50	0.40	0.10	0.10	0.10	0.20	0.10	0.10	0.20
	2	19.30	10.60	6.70	3.40	1.70	1.60	0.60	0.60	0.20	0.10	0.20	0.10	0.20	0.20
	3	15.80	14.60	6.20	3.50	1.60	2.10	1.80	0.50	0.20	0.10	0.20	0.10	0.10	0.10
	4	18.50	10.80	5.80	3.00	1.60	1.90	1.70	0.50	0.20	0.20	0.20	0.20	0.10	0.10
	5	19.30	10.90	7.50	4.40	2.10	2.60	2.30	1.00	0.50	0.20	0.20	0.20	0.20	0.20
YORK	Station	Y15	Y21	Y28	P36	P42		P45	P50	P55					
	1	17.50	13.20	9.80	3.10	0.60		0.20	0.10	0.10					
	2	17.40	ns	12.50	5.80	2.40		0.70	0.20	0.10					
	3	18.70	15.30	12.10	4.80	1.80		0.50	0.30	0.20					
	4	17.50	14.50	11.20	4.10	1.40		0.40	0.20	0.20					
	5	19.30	ns	12.50	5.60	2.20		0.80	0.40	0.20					
	Station				M33	M37	M41	M44	M47	M52					
	1				3.30	1.60	0.40	0.10	0.00	0.00					
	2				4.70	2.90	0.90	0.10	0.10	0.00					
	3				4.50	2.40	0.80	0.20	0.10	0.00					
	4				3.90	2.20	0.70	0.10	0.10	ns					
	5				5.50	3.20	1.10	0.30	0.10	0.10					
RAPPAHANNOCK	Station	R12	R21	R28	R37		R41	R44	R50	R55	R60	R65	R69	R76	
	1	ns	12.40	10.00	5.10		1.90	0.70	0.10	0.10	0.00	0.00	0.00	0.00	
	2	15.40	13.90	12.30	7.30		5.40	3.50	0.60	0.20	0.10	0.10	0.00	0.00	
	3	15.80	13.70	10.40	7.60		3.40	2.30	0.60	0.20	0.10	0.10	0.10	0.10	
	4	15.10	12.30	10.60	5.60		2.40	1.20	0.30	0.20	0.00	0.10	0.10	0.00	
	5	15.40	13.60	11.50	6.60		3.40	2.20	0.70	0.30	0.10	0.10	0.00	ns	

ns = no sample taken

Table 6. Water temperature (°C) recorded at 2001 seine survey stations. York system includes Pamunkey and Mattaponi Rivers.

Drainage															
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
	Round														
	1	28.70	29.70	28.50	25.50	28.20	27.60	26.90	29.50	27.60	27.40	29.10	29.90	32.00	29.80
	2	27.20	24.40	29.70	26.40	28.50	27.60	27.40	27.60	25.80	25.90	28.10	28.50	31.20	28.00
	3	29.50	29.10	30.50	26.40	30.40	28.50	28.60	35.00	25.80	25.50	28.20	28.80	27.80	27.80
	4	26.20	26.50	29.90	26.00	28.30	27.90	27.80	30.20	28.00	27.60	29.50	30.60	31.10	30.10
	5	26.20	24.90	28.00	24.50	26.80	26.40	26.60	27.40	27.00	26.50	27.30	29.30	30.80	28.40
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
	1	25.60	26.50	26.30	27.40	27.90		28.20	28.40	28.80					
	2	25.10	ns	25.70	26.80	27.70		27.70	27.60	28.90					
	3	30.30	30.00	27.70	28.00	28.60		29.00	29.50	31.50					
	4	28.30	29.10	25.70	27.70	28.30		28.40	28.40	29.40					
	5	26.60	ns	24.30	26.30	26.50		27.00	26.90	27.40					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	1				27.60	27.60	27.60	28.50	29.90	31.40					
	2				27.10	27.20	27.20	27.80	28.90	30.30					
	3				28.50	28.50	28.60	29.80	33.00	32.10					
	4				28.00	27.90	27.90	28.10	28.60	ns					
	5				26.90	26.70	26.50	26.80	27.60	27.90					
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	1	ns	26.70	23.40	24.30		24.90	26.00	27.70	28.10	27.60	25.70	27.80	27.50	
	2	26.50	26.70	28.50	29.10		30.40	31.30	27.20	27.40	27.50	27.10	27.90	28.50	
	3	27.00	28.90	27.90	29.10		30.00	30.80	26.20	26.40	26.00	26.20	26.00	25.90	
	4	28.80	25.20	27.60	29.30		28.60	29.70	28.60	28.70	28.10	27.30	27.80	26.10	
	5	28.00	25.40	25.50	26.50		27.70	28.40	27.90	27.70	28.00	27.40	28.20	ns	

ns = no sample taken

Table 7. Dissolved oxygen (milligrams per liter) recorded at 2001 seine survey stations. York system includes Pamunkey and Mattaponi Rivers.

Drainage														
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
	Round														
	1	6.50	8.20	7.40	7.10	8.40	7.60	6.20	8.30	6.70	8.30	10.80	6.20	5.70	6.30
	2	7.00	7.20	6.90	6.80	7.90	7.20	6.50	6.10	6.20	7.20	9.00	6.50	6.70	6.30
	3	6.60	6.90	7.40	6.50	9.30	8.00	4.80	6.90	6.70	8.10	12.10	7.50	8.40	6.80
	4	6.10	6.30	7.50	6.10	7.80	7.00	6.20	6.70	5.70	7.90	8.60	5.40	6.10	6.10
	5	4.40	6.90	7.10	6.00	8.50	6.50	7.00	6.70	6.40	7.90	8.70	6.50	7.20	6.40
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
	1	5.00	6.80	6.00	5.80	5.80		5.80	5.00	5.70					
	2	5.00	ns	6.30	4.90	5.40		6.00	5.30	5.50					
	3	6.50	6.80	3.80	4.70	5.60		5.70	5.60	6.70					
	4	7.90	8.40	5.50	4.10	4.40		5.20	5.40	5.20					
	5	5.50	ns	5.30	4.90	5.40		5.80	5.60	6.20					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	1				5.70	5.20	5.40	5.30	6.60	7.30					
	2				4.90	5.00	5.40	5.00	5.20	5.30					
	3				3.80	3.40	5.30	5.30	6.40	5.40					
	4				4.00	3.80	4.50	5.60	6.50	ns					
	5				6.30	5.90	5.70	5.70	5.30	5.40					
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	1	ns	7.40	7.10	7.50		6.50	8.10	7.10	7.30	6.90	8.30	7.10	6.70	
	2	4.80	5.70	7.50	6.50		6.30	6.80	5.70	6.40	5.50	6.90	6.10	7.10	
	3	5.60	6.60	6.10	7.10		5.90	7.20	8.00	8.10	7.10	6.20	5.10	7.30	
	4	7.20	6.40	7.60	7.30		6.70	7.70	7.10	7.20	6.50	7.70	5.20	4.40	
	5	7.40	7.30	7.10	7.70		6.60	8.10	6.50	6.20	6.30	7.00	4.60	ns	

ns = no sample taken

Table 8. pH recorded at 2001seine survey stations. York system includes Pamunkey and Mattaponi Rivers.

Drainage														
JAMES	Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J74	J78
	Round														
	1	7.10	8.20	8.10	8.00	8.70	8.50	7.90	8.80	8.20	8.60	9.50	7.60	7.80	7.90
	2	8.00	8.00	7.90	7.70	8.30	7.80	7.40	7.80	7.70	8.20	8.40	8.10	8.10	7.90
	3	7.90	7.70	8.00	7.60	8.70	8.00	7.60	8.00	8.00	8.70	9.30	7.60	8.30	8.30
	4	7.80	7.70	8.10	7.60	8.30	8.00	7.60	7.80	7.80	8.80	8.70	7.70	8.10	8.00
	5	7.80	7.90	7.90	7.60	8.40	7.80	7.70	7.90	7.90	8.70	8.60	8.00	8.40	8.30
YORK	Station	Y15	Y21	Y28	P36	**P42**		**P45**	**P50**	P55					
	1	7.50	7.80	7.60	7.30	7.40		7.50	7.50	7.50					
	2	7.60	ns	7.50	7.10	7.20		7.40	7.40	7.00					
	3	7.90	8.00	7.20	7.20	7.20		7.40	7.40	7.60					
	4	8.00	8.00	7.40	7.10	7.20		7.30	7.50	7.40					
	5	7.80	ns	7.40	7.20	7.20		7.40	7.50	7.50					
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	1				7.30	7.20	5.30	7.40	7.50	7.60					
	2				7.10	7.00	7.10	7.30	7.30	7.20					
	3				7.10	7.30	7.10	7.30	7.40	7.20					
	4				7.10	7.10	7.10	7.50	7.50	ns					
	5				7.40	7.30	7.30	7.40	7.40	7.50					
RAPPAHANNOCK	Station	R12	R21	**R28**	**R37**		R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	1	ns	7.90	7.70	7.70		7.40	8.00	7.80	7.80	7.90	8.90	8.10	7.70	
	2	7.80	7.60	7.10	7.40		7.40	7.80	7.50	7.70	7.80	8.00	7.70	8.00	
	3	7.80	7.90	7.60	7.60		7.40	8.10	8.00	8.10	7.70	7.60	7.40	7.70	
	4	8.10	7.30	7.90	8.00		7.50	8.70	7.90	7.90	7.80	8.20	7.40	7.30	
	5	8.10	7.70	7.70	7.80		7.60	8.10	7.70	7.70	7.70	7.80	7.50	ns	

ns = no sample taken

Table 9. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2001 summarized by salinity.

	2001				All Years Combined			
Salinity (ppt.)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)
0-4.9	2353	15.92	12.56-20.04	150	28950	7.73	7.33-8.15	3405
5-9.9	218	7.60	2.88-16.67	20	2054	3.89	3.32-4.53	450
10-14.9	53	7.73	3.37-15.45	10	189	1.46	1.06-1.90	149
15-19.9					2	0.13	-0.05-0.32	25
Overall	2624	14.17	11.33-17.60	180	31195	6.79	6.46-7.13	4029

Table 10. Catch of young-of-the-year striped bass per seine haul in the primary nursery area in 2001 summarized by water temperature.

	2001				All Years Combined			
Temp. (deg. C)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Adjust. Mean	C.I. (± 2 SE)	N (sites)
15-19.9					79	2.85	1.40-4.86	30
20-24.9	185	55.64	29.6-103.0	6	2077	3.19	2.77-3.66	581
25-29.9	2279	13.05	10.25-16.46	162	23680	7.86	7.41-8.33	2763
30-34.9	160	20.50	10.60-38.03	12	4969	7.96	6.96-9.07	556
Overall	2624	14.17	11.33-17.60	180	31195	6.79	6.46-7.13	4029

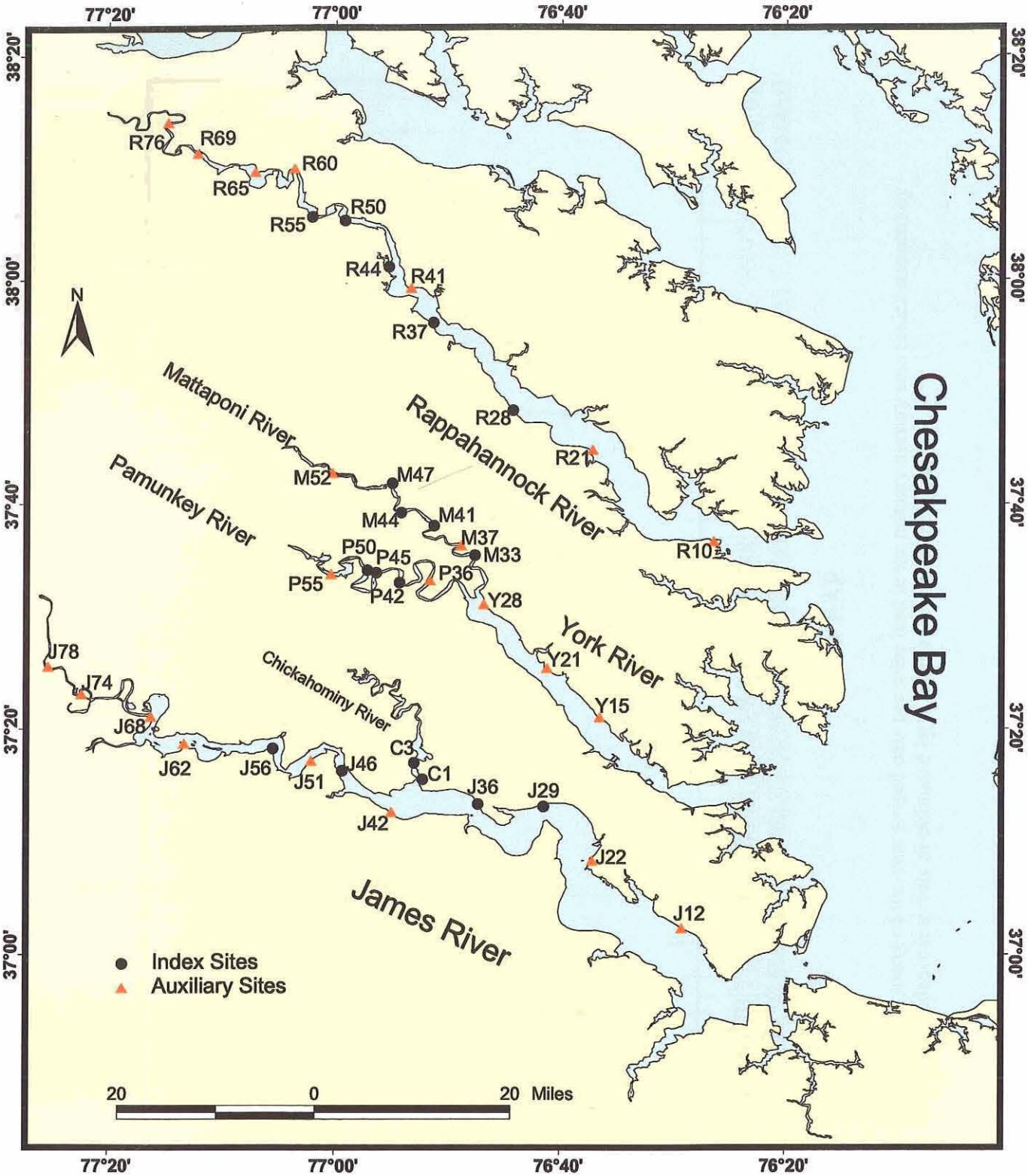

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designations indicate river mile from the mouth.

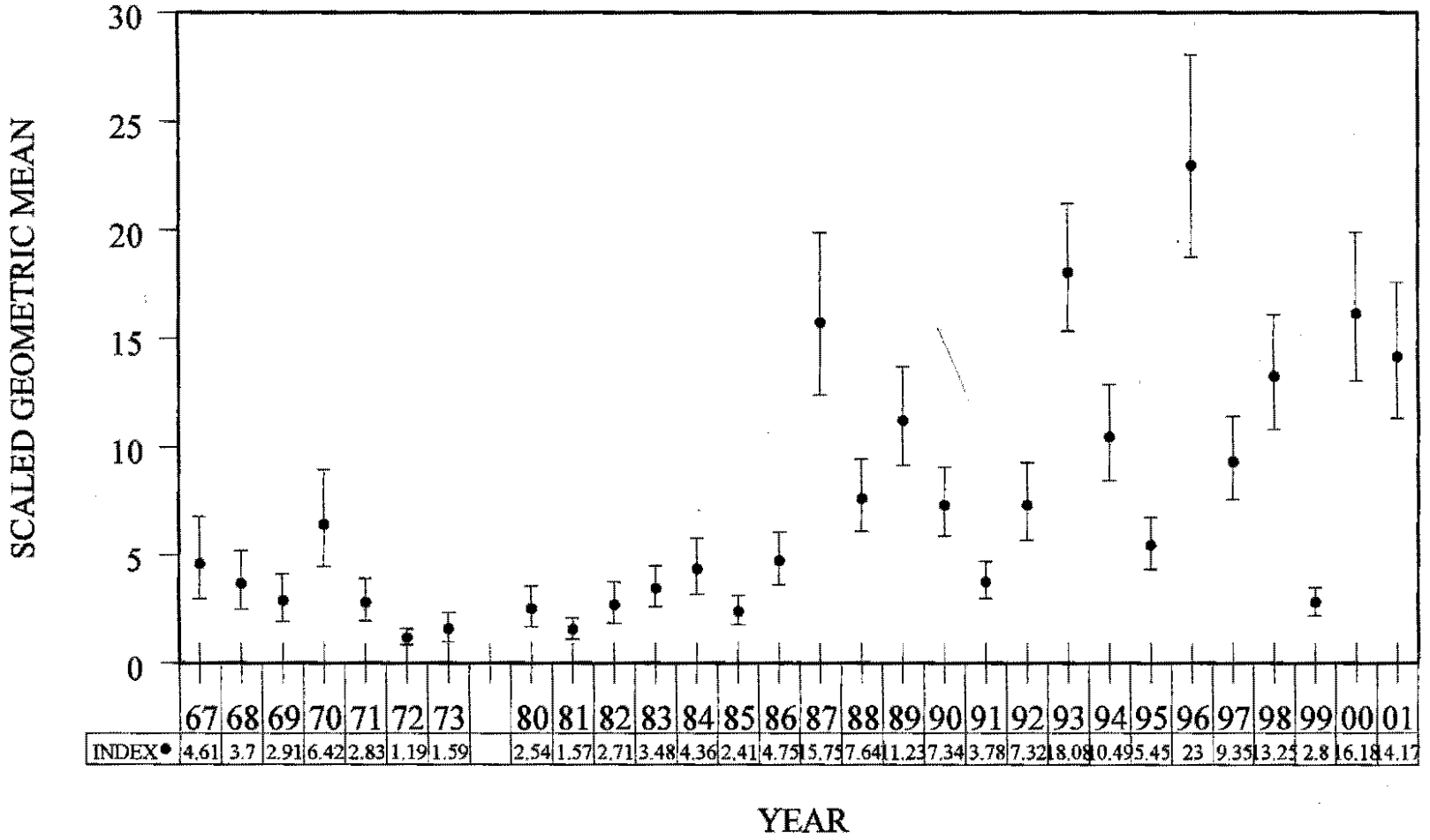

Figure 2. Scaled average catch of young-of-the-year striped bass per seine haul in the primary nursery area (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean.

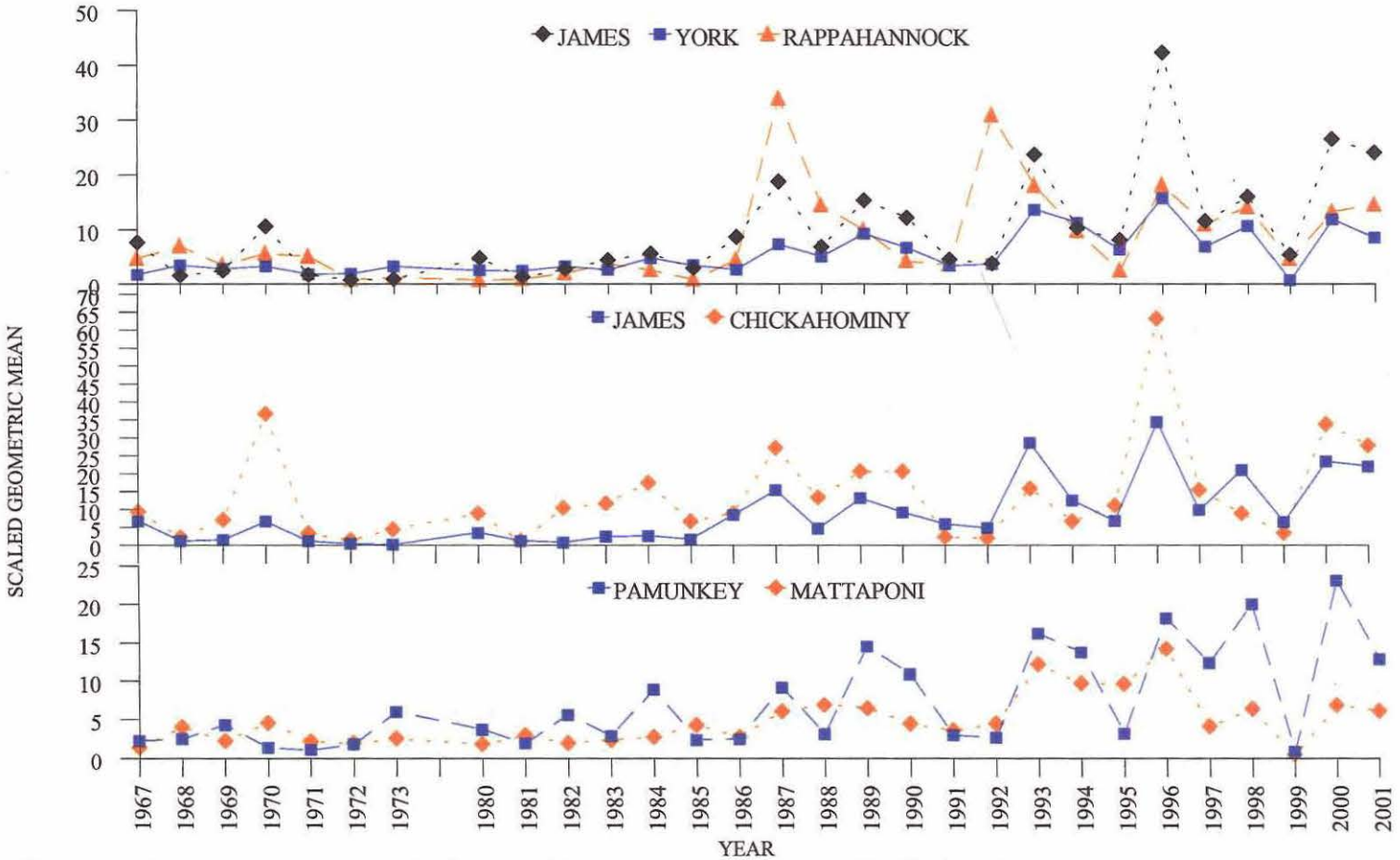

Figure 3. Adjusted average annual catch of young-of-the-year striped bass per seine haul in the primary nursery area by drainage and river.

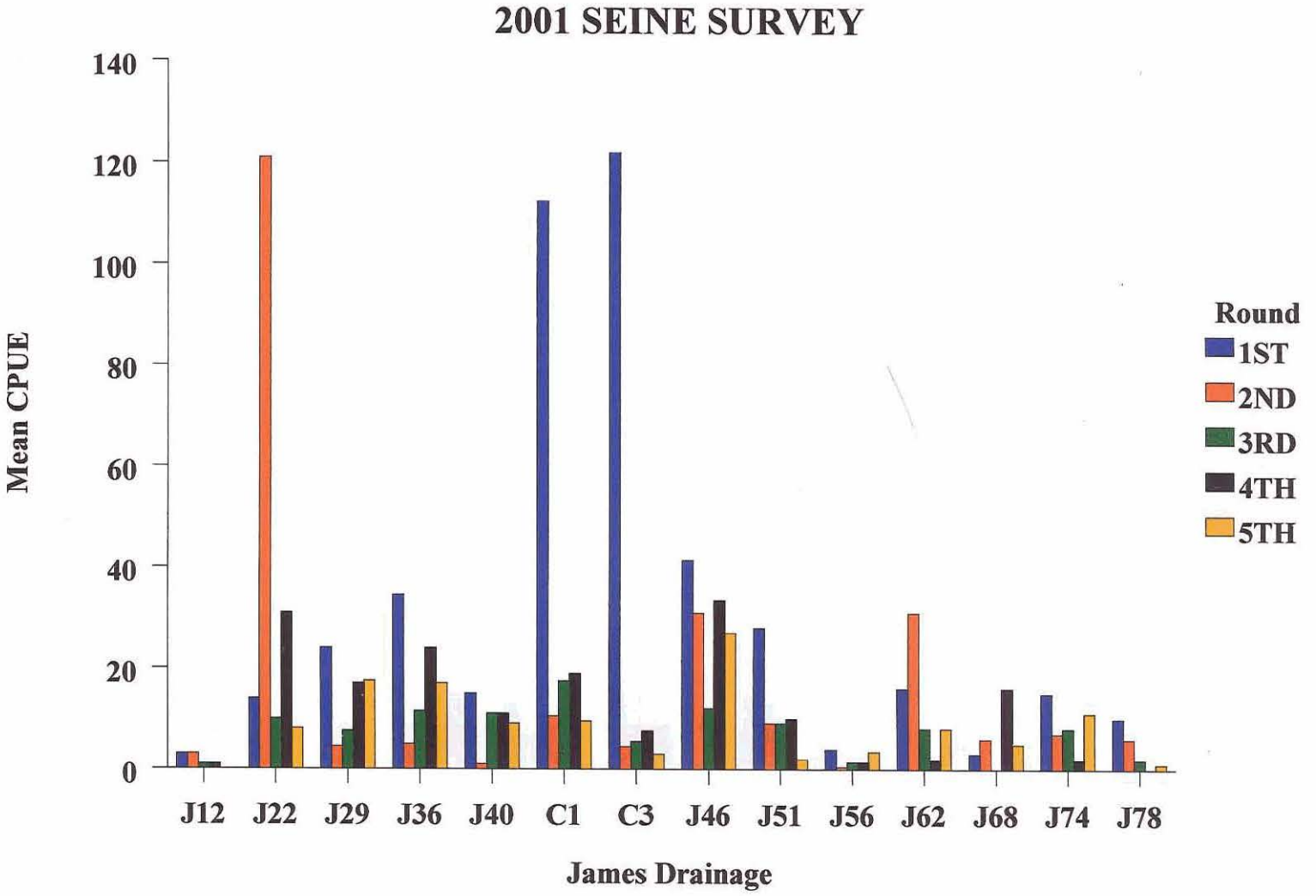

Figure 4. Average catch of young-of-the-year striped bass per seine haul by station in the James drainage.

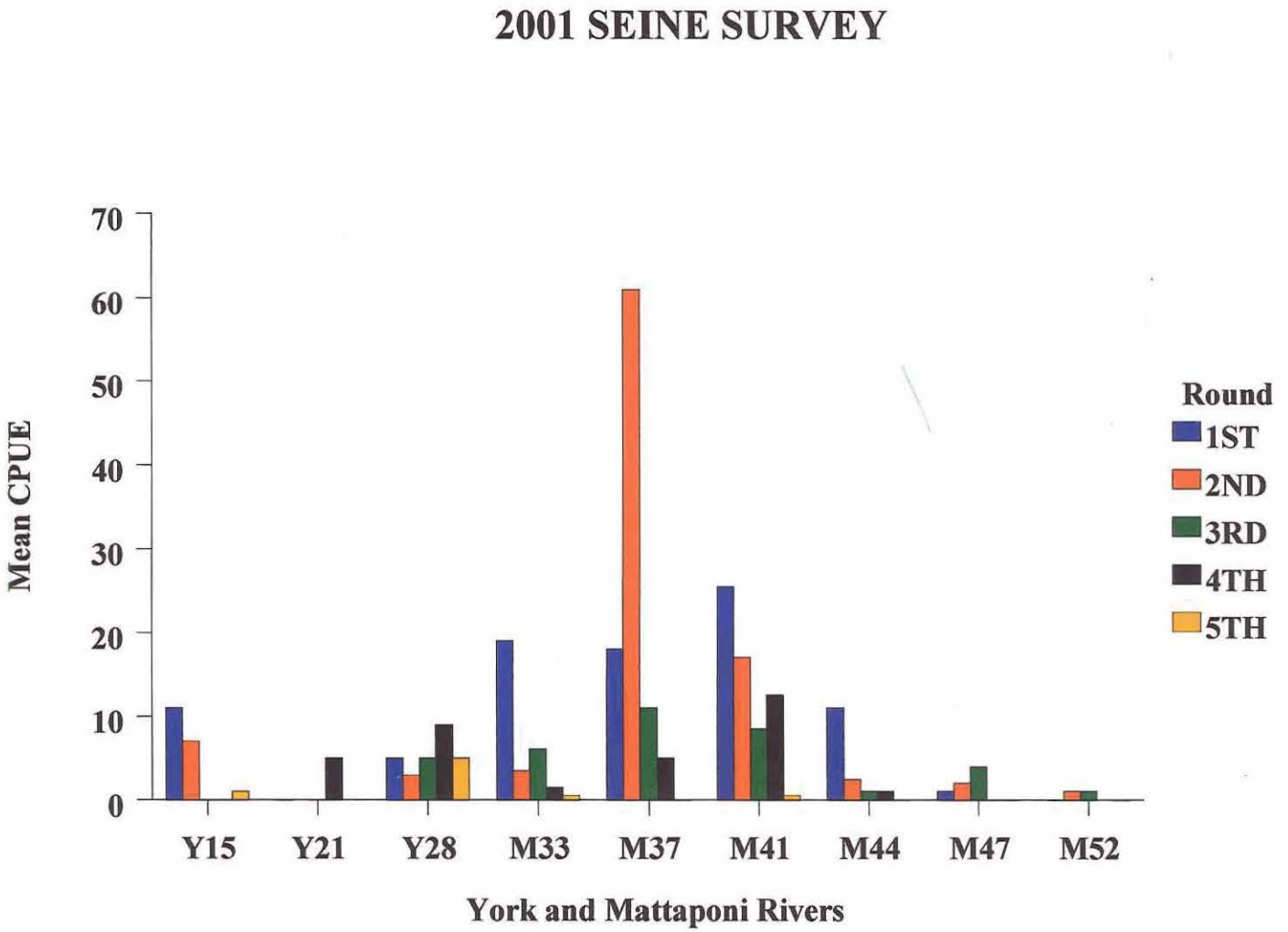

Figure 5. Average catch of young-of-the-year striped bass per seine haul by station in the Mattaponi and York rivers.

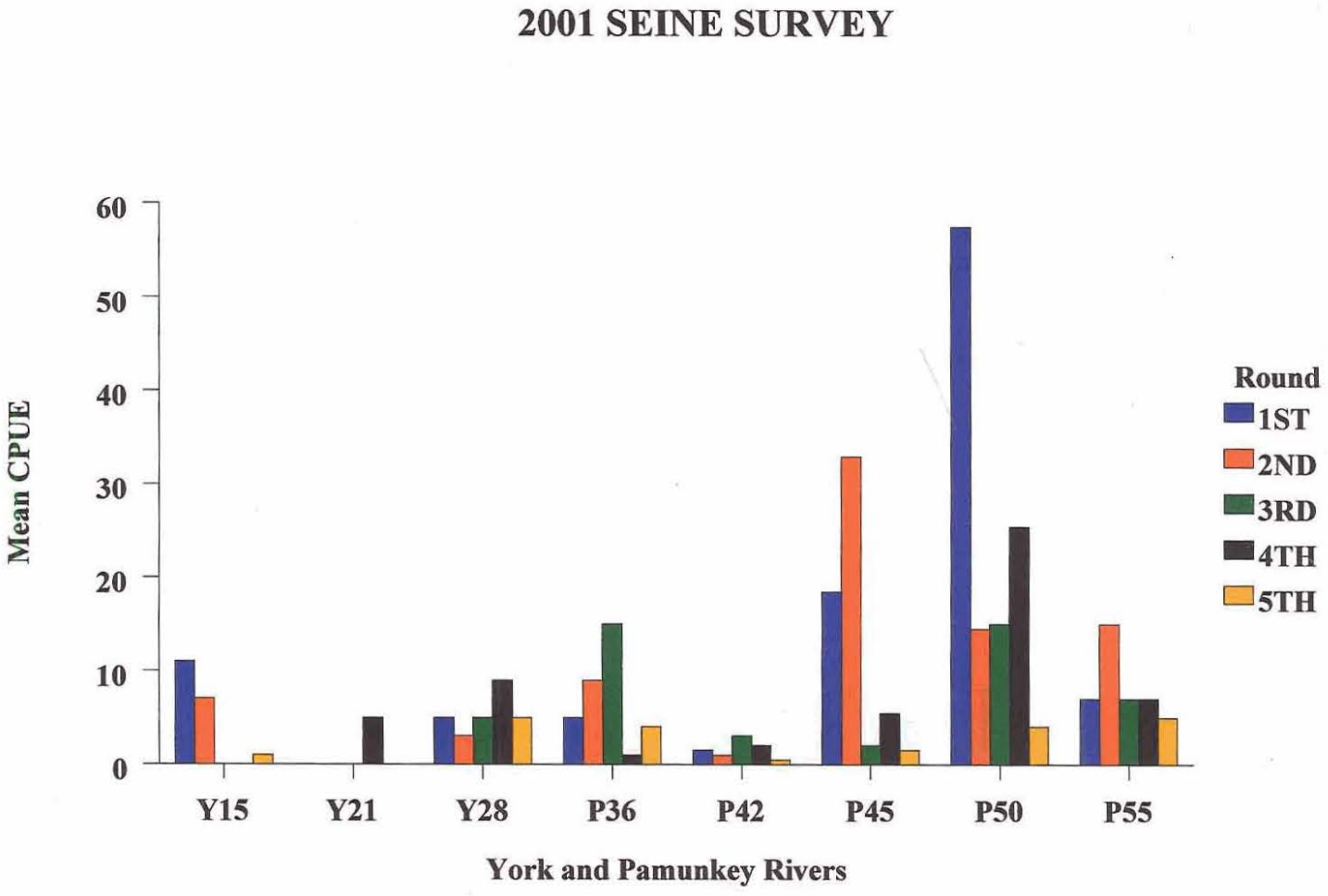

Figure 6. Average catch of young-of-the-year striped bass per seine haul by station in the Pamunkey and York rivers.

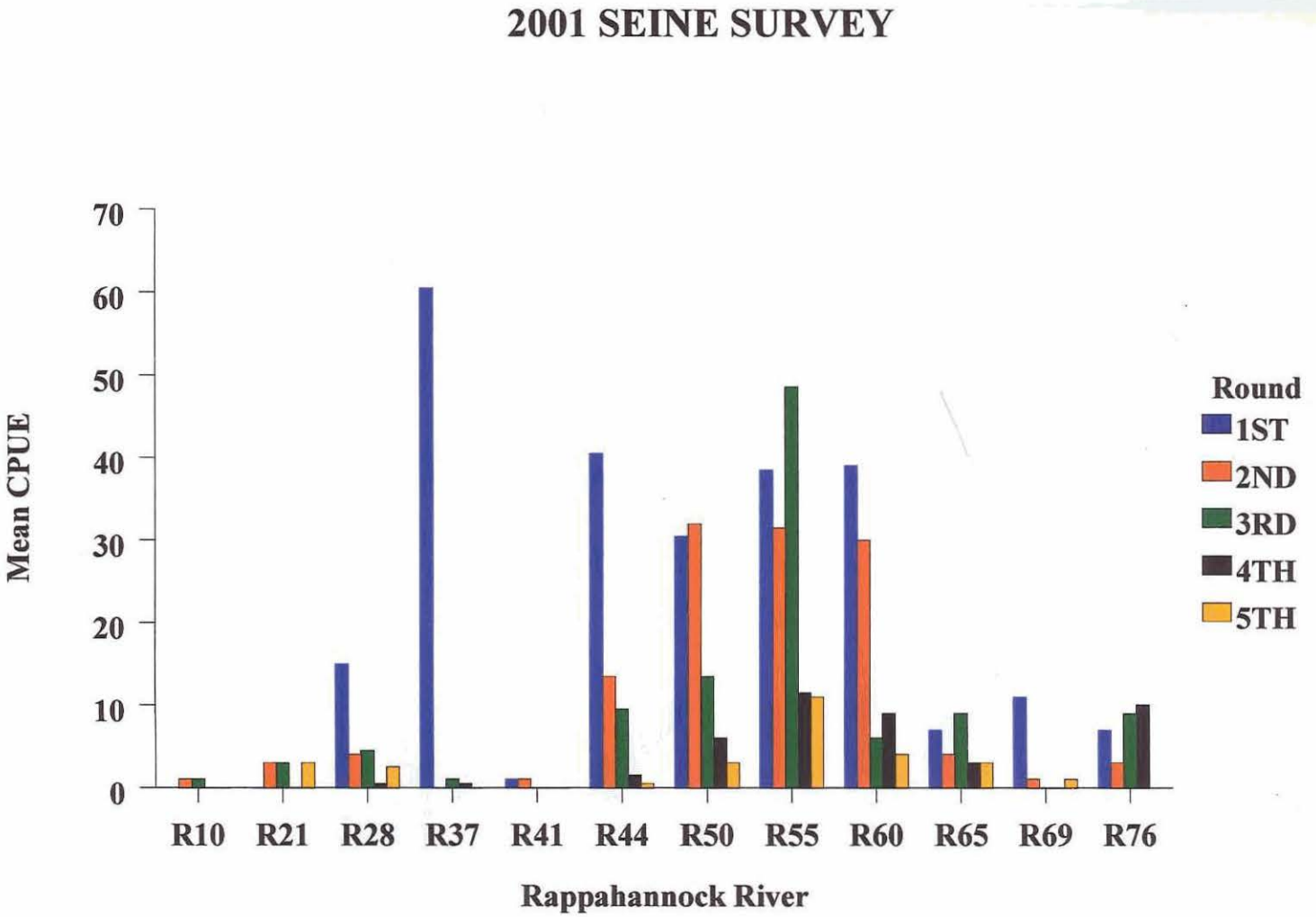

Figure 7. Average catch of young-of-the-year striped bass per seine haul by station in the Rappahannock River.

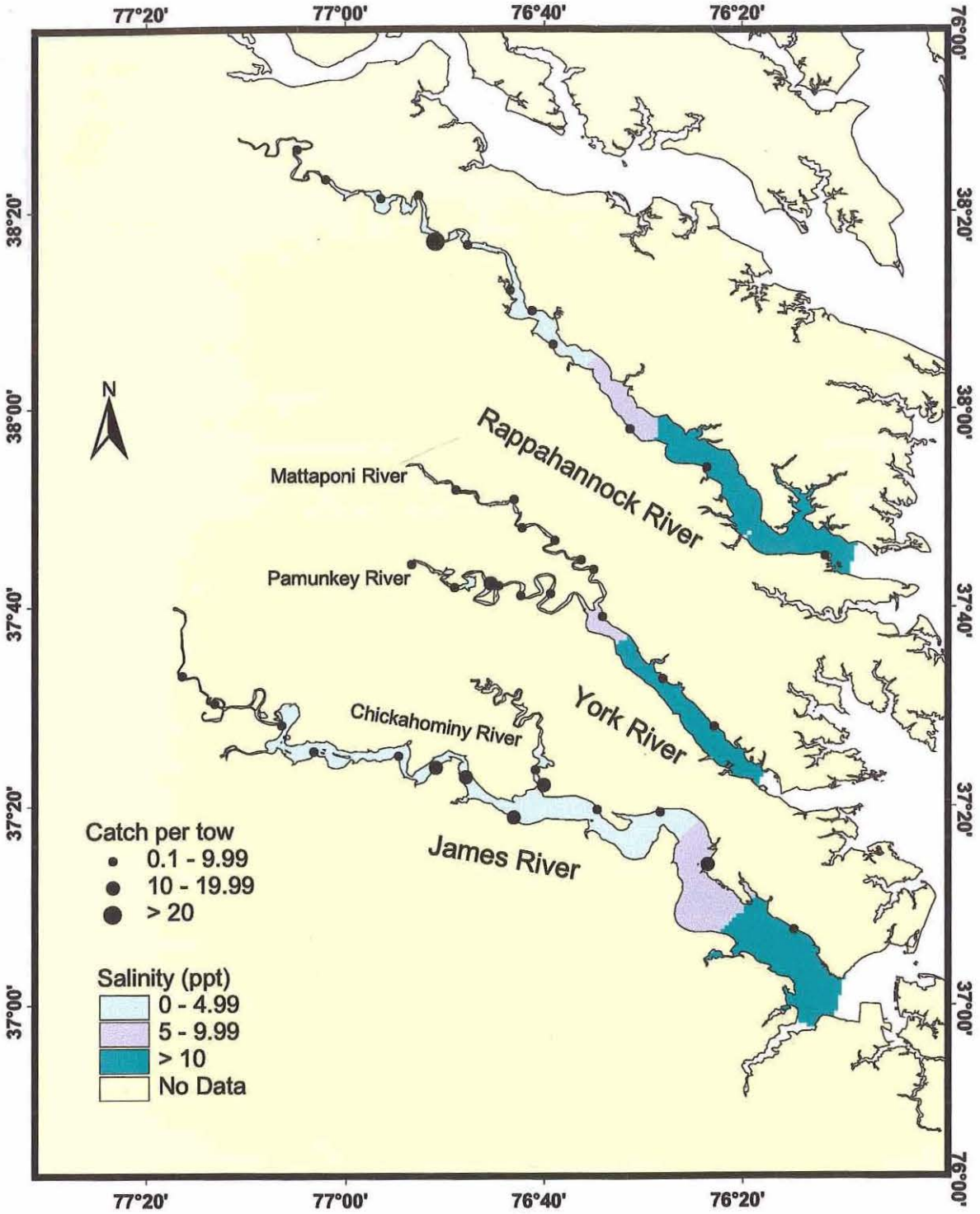

Figure 8. Catch per unit effort of young-of-the-year striped bass with respect to salinity from 1967-1999.

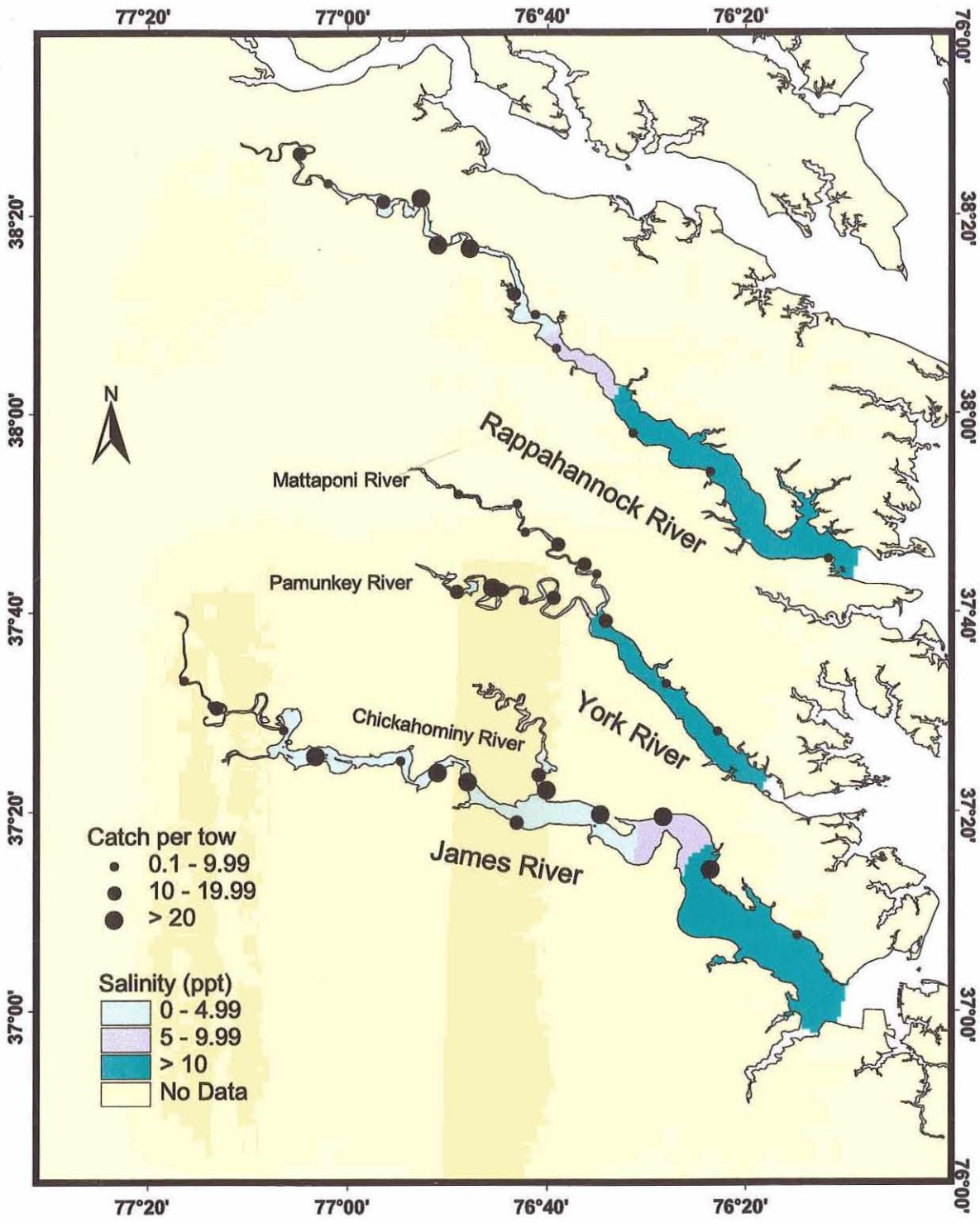

Figure 9. Catch per unit effort of young-of-the-year striped bass with respect to salinity in 2001.